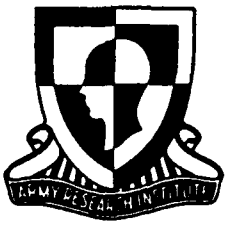

U.S. Army Research Institute
for the Behavioral and Social Sciences

Research Report 1639

Avenger Team Performance During Engagement Operations in a Chemical Environment

Joan D. Silver and John M. Lockhart
U.S. Army Research Institute

June 1993

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For this report, the effects of Mission Oriented Protective Posture (MOPP) on Avenger weapon system operation were tested in an engagement simulation facility. Two experiments were conducted, each using the Avenger system in a different mode of operation. The same teams participated in each experiment, but team members switched duty positions for the second experiment.

The team chief's ability to identify aircraft was significantly impaired by the MOPP gear in both modes of weapon system operation. The reduced field of view (FOV) created by the chemical protective (CP) mask is believed to have caused the MOPP4 performance decrement. The gunner, on the other hand, was not affected by the CP clothing, regardless of mode of weapon system operation. The advanced technology available to the gunner (easily seen displays and aids) seems to overcome the adverse effects of the MOPP gear.

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Research Report 1639

Avenger Team Performance During Engagement Operations in a Chemical Environment

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FOREWORD

The Crew Weapons Performance Team of the Fort Bliss Field Unit of the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) investigated the effect of the Mission Oriented Protective Posture (MOPP) clothing on the performance of air defenders. The investigation was part of an ongoing program of research sponsored by the Physiological and Psychological Effects of the Nuclear, Biological, and Chemical Environment and Sustained Operations on Systems in Combat (P^2NBC^2) program, U.S. Army Chemical School, Fort McClellan, Alabama. The results of these investigations established that Stinger and Avenger team chief performance is impaired by the MOPP gear. Stinger gunner performance is not impaired. The reduced field of view (FOV) caused by the chemical protective (CP) mask is the source of the performance decrement seen in this research. It is likely that the technological advantage afforded to the Avenger gunner by easily seen displays and aids, which are not available to the Stinger gunner, overcomes the negative effects of the MOPP gear.

The proponent for the Avenger research, the Directorate of Combat Developments, Fort Bliss, Texas, reviewed the results of this research and submitted an abbreviated operational assessment to the P^2NBC^2 program. The results suggest that the Avenger weapon system, not the Stinger weapon system, is the better choice in a chemical environment because of the immunity to the negative effects of the MOPP gear afforded to the Avenger gunner.

EDGAR M. JOHNSON
Acting Director

AVENGER TEAM PERFORMANCE DURING ENGAGEMENT OPERATIONS IN A CHEMICAL ENVIRONMENT

EXECUTIVE SUMMARY

Requirement:

This research investigates the effect of the Mission Oriented Protective Posture (MOPP) clothing on the Avenger weapon system.

Procedure:

The effects of MOPP gear on Avenger teams engaging subscale aircraft in a simulation facility were investigated. Two experiments were conducted. Each experiment employed the same teams (team chief and gunner) using the Avenger weapon system in a different mode of static defense emplacement. Team members switched duty positions for the second experiment.

Findings:

Team chief performance was significantly impaired by the MOPP gear, regardless of weapon system mode of operation. The reduced field of view (FOV) caused by the chemical protective mask is believed to be the primary source of the impaired performance. The MOPP gear had no impact on Avenger gunner performance in either mode of weapon system operation. The technological advantage afforded to the Avenger gunner by easily seen displays and aids is believed to overcome adverse effects of the MOPP gear.

Utilization of Findings:

It is possible that the detrimental effects of the chemical protective mask on team chief performance may be negated by a cuing device that provides precise information and/or by binoculars modified to restore the FOV. It is also possible that the Avenger weapon system, rather than Stinger, may be the better choice on a battlefield subject to chemical attack because its easily seen displays and aids largely offset the negative effects of the MOPP gear.

AVENGER TEAM PERFORMANCE DURING ENGAGEMENT OPERATIONS IN A CHEMICAL ENVIRONMENT

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AVENGER TEAM PERFORMANCE DURING ENGAGEMENT OPERATIONS IN A CHEMICAL ENVIRONMENT

Introduction

Current doctrine requires that Air Defenders engage hostile aircraft while operating in a chemically contaminated environment. Operations in a contaminated environment require the use of a flexible system of protection called Mission Oriented Protective posture (MOPP), which affords five levels of protection, MOPP0 through MOPP4. A soldier in MOPP0 is attired in battle dress uniform, carries a chemical protective (CP) mask, and has the other elements of the protective gear readily available to him. In MOPP4, the soldier is encased in a CP overgarment, rubber boots, gloves, and a protective mask. Encapsulation in MOPP4 can present unique physiological and psychological problems that may limit the amount of time a soldier can remain in the protective clothing and still effectively perform his mission.

The present study investigated the effect of MOPP gear on a group of Air Defenders (Avenger teams) engaging subscale aircraft in a simulation facility. Two experiments were conducted. Each experiment employed the same teams (team chief and gunner) using the Avenger weapon system in a different mode of static defense emplacement. Team members switched duty positions for the second experiment.

It was hypothesized that the engagement performance of the Avenger teams would be significantly impaired by the CP clothing regardless of mode of operation of the weapon system. It was also hypothesized that wearing MOPP gear would increase perceptions of workload and stress.

Experiment 1

Method

The purpose of this experiment was to test the effects of CP clothing on operation of the Avenger weapon system when used in the static stationary deliberate emplacement mode. This mode of operation requires the gunner to remain in the turret while the driver monitors squad actions at the remote control until (RCU), which has been removed from the vehicle and placed away from the weapon system. The RCU displays the same information available to the gunner in the turret and it can be located anywhere within 50 meters of the fire unit. All target acquisition and fire control functions are replicated in the RCU. Although the team chief and the gunner are not in the same physical location, they are able to communicate with each other via combat vehicle crewman helmets (FM 44-31, 1989).

Participants

Six Avenger teams, each composed of a team chief and a gunner, participated in this research. Ages ranged from 20 to 29 years (M = 23.33). The group was comprised of five privates first class, 3 specialists, and four sergeants.

Apparatus

Range Target System. The Avenger teams were tested at the Range Target System (RTS) engagement simulation facility located at White Sands Missile Range, New Mexico. Short Range Air Defense (SHORAD) and Forward Area Air Defense (FAAD) crews can employ their actual weapons or use training devices in simulated or live fire engagement of subscale fixed-wing and rotary-wing aircraft in this facility. The fixed-wing aircraft are remotely piloted and the rotary-wing aircraft pop up from predetermined locations via pneumatic standlift mechanisms.

Avenger weapon system. The Avenger fire unit is comprised of a turret mounted in the rear bed of the high-mobility, multipurpose wheeled vehicle (HMMWV) chassis. Four Stinger missiles are carried in each of two pods mounted on launch beams on either side of the turret. Avenger has the capability to engage under adverse weather conditions and at night using the automated target acquisition, tracking, and fire control subsystems ("The soldier," 1992).

The major components of the fire unit are the missile pods, a .50-caliber machine gun, forward-looking infrared (FLIR), laser range finder (LRF), and identification, friend or foe (IFF). Avenger can "shoot on the move" or from a stationary position with the gunner in the turret. It can also be operated from a remote location.

The Avenger weapon system is operated by a two-man squad consisting of a driver (team chief) and a gunner. Because either team member may perform as gunner or driver, both squad members must be trained to perform all tasks associated with both positions. Frequent exchange of positions is expected to maintain a high degree of mission effectiveness.

Both the gunner and the team chief are assisted in engagement operations by the FLIR sensor that follows the elevation aiming point of the missile pod. Handstations for manual tracking control and conduct of engagements are positioned in the turret and on the RCU. An automatic video tracker (AVT) and its tracking box are located on the FLIR display. The AVT locks onto the target and provides a tracking signal to the Avenger control electronics (ACE) for control of the turret in azimuth and elevation until engagement is completed or the AVT is deactivated. The ACE is the main computer that controls the entire system.

The gunner is aided in the turret by a heads-up display (HUD) optical sight which projects all essential engagement information onto the sight glass. This information includes missile seeker activation, uncaging of the missile gyro, and a sight reticle driven by the missile seeker which centers on the IR source. The HUD ensures that the missile seeker is locked onto the same target the gunner is seeking. An eye-safe laser rangefinder (LRF) provides target range information ("The soldier," 1992).

A control display terminal (CDT) is mounted in front of the gunner to the left of the FLIR monitor and is removable to the RCU for remote operation. The CDT displays essential information and allows the gunner or RCU crew to interface with the ACE (FM 44-31, 1989).

Participants in this experiment did not use the LRF because the engagement simulation facility presents subscale targets at scaled distances. The AVT also was not used; participants were required to track in the manual mode to reveal the effects of MOPP gear on team performance.

The Avenger weapon system is generally operated in the static defense mode. Static defense is primarily used when defending stationary assets such as support activities, command and control elements (C^2), or choke points and bridges. Defense of static assets behind the maneuver forces is planned essentially to counter low-level attack by jet aircraft and helicopters. Static critical assets are normally located well behind the forward edge of the battle area which permits the positioning of weapons away from the asset in any direction (FM 44-31, 1989).

Procedure

A total of six Avenger teams were tested; three teams on each test day. Informed consent was given by each participant.

Three Avenger weapon systems were cabled to RTS Data Acquisition Stations (DAS). One data collector was assigned to each DAS. Gunner actions such as "IFF" and "fire" were captured automatically by the DAS. Team chief actions such as "detect" and "identify" were entered manually on the keyboard by each data collector.

Each Avenger team was assigned a 90° sector of responsibility. A primary target line was designated for each team using a fixed marker and the outer limits of the sector were defined for each team.

Each engagement trial began with the verbal alert "Red Tight" (air activity imminent; positive hostile ID required) given by the data collector assigned to the team and concluded with the verbal alert "Condition Yellow" (air attack has subsided). Between engagement trials, the team chief and the

turret of the Avenger weapon system were positioned facing east, away from their sector of responsibility. At the verbal alert "Red Tight" the team chief turned south, facing his sector of responsibility, and simultaneously cued the gunner to slew the turret to the south; both team members then began searching and scanning for aircraft. The team chief gave a verbal and a manual signal to the data collector when he detected an aircraft and again when he identified the aircraft and gave the engagement command ("Hostile, Engage" or "Friendly, Cease Fire"). At the end of the trial the team chief and the turret were again positioned facing east.

Thirteen engagement trials were administered in the morning and thirteen in the afternoon. Conditions of CP clothing were counterbalanced over DASs (see Figure 1). Four separate but equivalent sets of scenarios were developed and they were counterbalanced over test days (see Figure 2). Scenarios varied in difficulty. A scenario could contain one pop-up helicopter, one fixed-wing aircraft, a mix of one pop-up and one fixed-wing, or multiple pop-ups (not to exceed three in number). The aircraft could be friendly (US), hostile (Soviet), or a mixture of both.

Mean ambient temperatures in the morning were 56.4°F and 60.9°F, day 1 and day 2 respectively, and 57.4°F and 65.4°F in the afternoon.

TIME OF DAY	DAY 1			DAY 2		
	DAS 1	DAS 2	DAS 3	DAS 1	DAS 2	DAS 3
AM	MOPP0	MOPP4	MOPP0	MOPP4	MOPP0	MOPP4
PM	MOPP4	MOPP0	MOPP4	MOPP0	MOPP4	MOPP0

Figure 1. Experiment 1 MOPP level counterbalancing plan.

TIME OF DAY	DAY 1			DAY 2		
	DAS 1	DAS 2	DAS 3	DAS 1	DAS 2	DAS 3
AM	SCENARIO SET A			SCENARIO SET D		
PM	SCENARIO SET B			SCENARIO SET C		

Figure 2. Experiment 1 scenario set counterbalancing plan.

Before and after each set of MOPP0 and MOPP4 engagement trials, participants responded to a Self-Evaluation Questionnaire (SEQ). This questionnaire assesses state anxiety which is a reaction or process taking place at a given time and level of intensity (Spielberger, 1983). The scale consists of 20 statements intended to evaluate how respondents feel at that particular moment.

After each engagement trial participants rated workload using the National Aeronautics and Space Administration (NASA) Ames Task Load Index (TLX) rating scale (NASA-Ames, 1986). The TLX is a multidimensional rating procedure that derives an overall workload score from six subscales--mental demand, physical demand, temporal demand, effort, performance, and frustration.

An ambulance and medics were present throughout each test day in the event of a medical emergency.

Results and Discussion

Two general classes of performance measures were collected--Task Performance Measures (TPM) and Summary Performance Measures (SPM). TPM are expressed as ranges for the fixed-wing aircraft (range to detect, range to IFF, etc.) and as elapsed time for rotary-wing aircraft (time from target available to detect, time from ID to fire, etc). TPM are available on a trial-by-trial

basis. SPM are collected by summing over scenarios and are expressed as percentages (e.g., percent aircraft detected, percent aircraft killed prior to ordnance release). The TPM are presented first. Because of the small sample size and the large variability commonly found in applied field research a significance level of .10 has been set for the TPM and SPM.

Task Performance Measures

Fixed-wing TPM. Table 1 contains the fixed-wing TPM means, standard deviations, number of observations, and results of the single factor repeated measures analyses of variance (ANOVA) (Norusis, 1986, pp. B153-B181) performed on each of the dependent measures. The TPM means appear in graphic form in Figure 3.

Data were collected on five fixed-wing TPM. DETECT is the range of the aircraft when the detection response is given by the team chief. IFF is the range of the aircraft at the identification, friend or foe button push made by the gunner. ID is the aircraft range when the team chief makes a "friendly" or "hostile" identification. UNCAGE VERIFY is the range at which the gunner uncages the missile seeker head. FIRE is the aircraft range at the gunner's trigger pull.

Although each of the fixed-wing TPM comparisons was as expected--performance was better in MOPP0 than when the CP ensemble was worn--only two of these measures were significantly affected by the MOPP gear. The ability of the team chief to detect and to identify fixed-wing aircraft was impaired by the CP clothing. None of the events related to gunner actions (IFF, UNCAGE VERIFY, FIRE) was significantly degraded by the protective clothing. Thus, based on our findings, when engaging fixed-wing aircraft in the static stationary deliberate mode of operation, the CP ensemble impairs the performance of the Avenger team chief, but not that of the gunner.

These results make sense when each team member's responsibilities and the equipment each has to assist him in performing these responsibilities are taken into account. First consider the equipment common to both team members, the MOPP gear, which includes an overgarment, gloves, boots and protective mask. Previous research with other Air Defenders (Johnson & Silver, 1992; in press) isolated the mask as the element of the CP clothing which was the likely source of the performance decrement seen when MOPP gear was worn. The mask creates a standoff from the eye to the lens (Harrah, 1985) which when combined with use of binoculars or Stinger sight results in a field of view (FOV) which is reduced by over 50 percent. It is the reduced FOV which accounts for the performance decrement (Silver and Lockhart, in preparation).

The results from the present study show that only the team chief's performance was impaired by the CP mask. Taking into account the responsibilities of each team member, these results also make sense. Consider that the team chief detected aircraft

with the unaided eye and then, for this test, was required to make positive visual identification of the aircraft using his binoculars in combination with the CP mask. He had to accomplish this task while tracking fast-moving, maneuvering, fixed-wing aircraft in a dynamic environment within a FOV which was reduced by more than half.

Table 1

Experiment 1 Mean Fixed-Wing TPM

	MOPP0	MOPP4	RESULTS
DETECT (km) Alerted Trials			
Mean	9.54	7.58	$F(1,5) = 6.83$ *
SD	7.30	1.62	
N	6	6	
IFF (km)			
Mean	5.57	4.59	$F(1,5) = .45$
SD	4.47	1.65	
N	6	6	
ID (km)			
Mean	5.35	3.59	$F(1,5) = 6.95$ *
SD	1.53	8.70	
N	6	6	
UNCAGE VERIFY (km)			
Mean	3.00	1.49	$F(1,5) = 3.47$
SD	1.81	8.17	
N	6	6	
FIRE (km)			
Mean	2.47	1.30	$F(1,5) = 2.21$
SD	1.82	8.69	
N	6	6	

* $p<.05$

By way of contrast, the gunner is assisted in performing his job by easily seen displays and aids which are viewed along the horizontal axis, an area of the visual field least impaired by the mask (Kobrick & Sleeper, 1986). Given the lack of significant impact of the MOPP gear on gunner performance, it appears that the technological advantage provided by his displays and aids overcomes the problems associated with the protective

mask and thus likely accounts for the absence of a significant MOPP4 performance decrement.

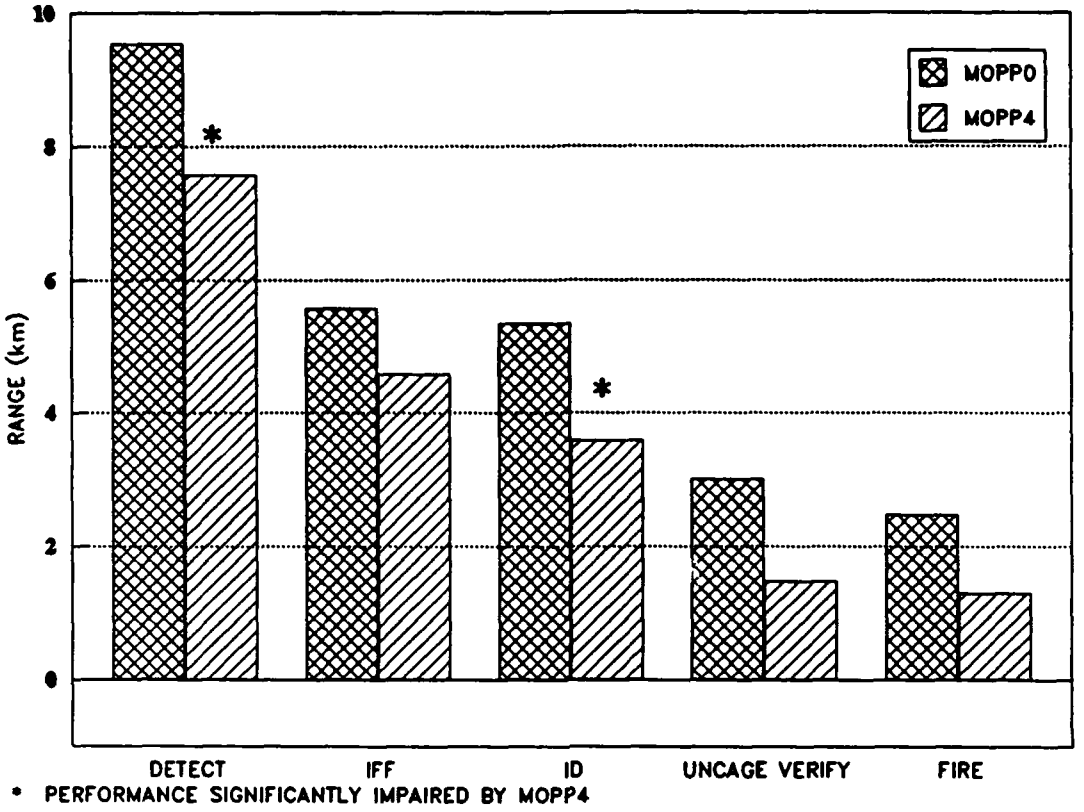

Figure 3. Experiment 1 MOPP0--MOPP4 mean fixed-wing TPM.

Rotary-wing TPM. The rotary-wing TPM means, standard deviations, number of observations, and results of the repeated measures ANOVA performed on these data are listed in Table 2. Figure 4 is a graphic representation of the TPM means. AVL-DET is the time from availability of the target until the team chief makes the detection response. DET-IFF is the time from the team chief's detection response until the gunner depresses the identification friend or foe button. DET-ID is the time from the detection response until the team chief identifies the aircraft as hostile or friendly. ID-UNCVER is the elapsed time from the team chief's identification to the time when uncaging of the missile gyro is verified. ID-FIRE is the elapsed time from the identification of the aircraft to trigger pull by the gunner. DET-FIRE is the elapsed time from detection of the aircraft to trigger pull. AVL-FIR is the elapsed time from target availability to trigger pull.

Like fixed-wing targets, the team chief's ability to identify rotary-wing aircraft was significantly impaired by the MOPP gear. The reduced FOV caused by the CP mask in combination

Table 2

Experiment 1 Mean Rotary-Wing TPM

	MOPP0	MOPP4	RESULTS
AVL-DET (Alerted Trials)			
Mean	8.90	10.30	F(1,5) = .52
SD	3.02	2.75	
N	6	6	
DET-IFF			
Mean	5.65	6.72	F(1,5) = .71
SD	3.14	3.28	
N	6	6	
DET-ID			
Mean	9.18	11.45	F(1,5) = 5.66 *
SD	2.74	1.99	
N	6	6	
ID-UNCVER			
Mean	17.70	12.65	F(1,5) = 4.39 **
SD	9.35	5.99	
N	6	6	
ID-FIRE			
Mean	13.53	8.67	F(1,5) = 4.38 **
SD	10.36	5.09	
N	6	6	
DET-FIRE			
Mean	21.60	19.10	F(1,5) = .30
SD	12.36	7.17	
N	6	6	
AVL-FIRE			
Mean	28.27	29.33	F(1,5) = .09
SD	10.62	3.92	
N	6	6	

* $p<.06$
** $p<.09$

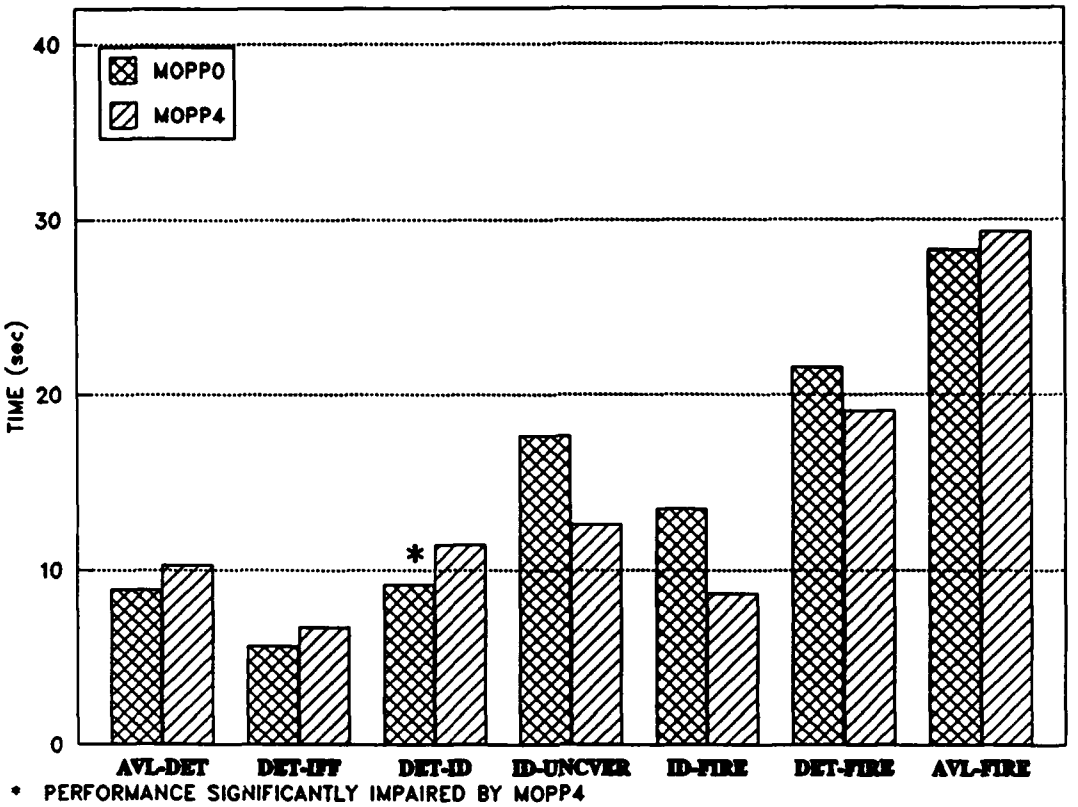

Figure 4. Experiment 1 MOPP0--MOPP4 mean rotary-wing TPM.

with the binoculars is invoked once again as the source of this performance decrement.

There were two other significant findings and both were unexpected and contrary to predictions. The times from the identification of aircraft to uncage verify (ID-UNCVER) and from identification of aircraft to the fire response (ID-FIRE) were significantly longer in MOPP0 than in MOPP4. Although MOPP0 means are sometimes larger than MOPP4, it is unusual for TPM to take significantly longer in MOPP0.

The ID-UNCVER means were also unusual in another sense; the elapsed time for this event was longer than the elapsed time for the ID-FIRE event. This should not happen because "uncage verify" occurs prior to "fire" in the engagement sequence. Because this was such an unusual circumstance, not seen before in any of our prior research investigating the effects of CP clothing, these data were reexamined. First we confirmed that they had been recorded and entered into the data base accurately. Second, we extensively reanalyzed the data and these analyses revealed that the ID-UNCVER means for this group of Avenger participants were composed of two significantly different subgroups; those for whom "uncage verify" was the last act in the engagement sequence and those for whom "fire" was the last act in the sequence. "Uncage verify" would be the last act

when an aircraft had been declared friendly and "fire" would be the last act when an aircraft was declared hostile.

As seen in Table 3 , the time from "identification" to "uncage verify" was almost 2 1/2 times longer in MOPP0 and close to three times longer in MOPP4 if an aircraft had been declared friendly. These data strongly suggest that for these Avenger participants the processing of "friendly" information takes much longer than when making a "hostile" determination. Certainly if a team chief has any indication that the aircraft might be friendly, the cost-benefit ratio supports taking the time to be sure, particularly for U.S. rotary-wing targets which are generally smaller than their hostile counterparts.

Table 3

Experiment 1 "Last Act" Means

	Last Act	
	Uncage Verify (Friendly)	Fire (Hostile)
	MOPP0	
Mean	28.08	11.61
SD	5.10	10.62
N	5	6
	MOPP4	
Mean	20.42	7.27
SD	13.61	4.85
N	3	5

Summary Performance Measures

SPM are expressed as percentages. The percent aircraft detected is the number of aircraft detected divided by the total number of aircraft presented. The percent aircraft identified correctly is the number of aircraft for which a correct identification response is given divided by the total number of aircraft detected. The percent friendly aircraft identified correctly is the number of friendly aircraft for which a correct identification response is given divided by the total number of friendly aircraft detected. The percent hostile aircraft identified correctly is the number of hostile aircraft for which a correct identification response is given divided by the total number of hostile aircraft detected.

Attrition is defined as the number of hostile aircraft credited as "killed" divided by the total number of hostile aircraft presented. Fratricide is the number of friendly aircraft credited as "killed" divided by the total number of friendly aircraft presented. The number of hostile aircraft "killed" prior to ordnance release is divided by the total number of hostile aircraft presented to calculate that percentage. Ordnance release is defined as 2 km from the weapon for fixed-wing aircraft and 20 sec after target availability for rotary-wing aircraft. The probability of kill given fire is the number of aircraft credited as "killed" (hostile plus friendly) divided by the total number of fire events (trigger pulls).

Fixed-wing SPM. The fixed-wing SPM means, standard deviations, number of observations, and results of the repeated measures analyses are listed in Table 4. The SPM means are depicted graphically in Figure 5.

None of the fixed-wing SPM was significantly impacted by the MOPP gear. All of the aircraft presented were detected under both MOPP clothing conditions. There were no significant differences in the percentage of aircraft identified correctly in either MOPP0 or MOPP4 and there were no instances of fratricide. It can be concluded therefore that the MOPP gear has no effect on overall fixed-wing mission success as represented by these measures. The findings are generally consistent with those from prior Stinger research (Johnson & Silver, 1992; in preparation).

Table 4

Experiment 1 Mean Fixed-Wing SPM

	MOPP0	MOPP4	RESULTS
Percent Detected (Alerted Trials)			
Mean	100.00	100.00	
SD	0	0	
N	6	6	
Percent Identified Correctly			
Mean	93.33	86.67	F(1,5) =.45
SD	10.33	16.33	
N	6	6	
Percent Friendly Aircraft Identified Correctly			
Mean	100.00	75.00	F(1,5) = 2.14
SD	0.0	41.83	
N	6	6	
Percent Hostile Aircraft Identified Correctly			
Mean	89.00	94.50	F(1,5) = .29
SD	17.04	13.47	
N	6	6	
Percent Attrition			
Mean	72.17	72.50	F(1,5) = 0
SD	32.92	13.47	
N	6	6	
Percent Fratricide			
Mean	0.0	0.0	
SD	0.0	0.0	
N	6	6	
Percent Hostile Aircraft "Killed" Prior to Ordnance Release			
Mean	38.83	27.67	F(1,5) = .98
SD	25.29	25.15	
N	6	6	
Probability of Kill			
Mean	83.33	78.00	F(1,5) = .27
SD	27.97	17.04	
N	6	6	

All comparisons are non-significant

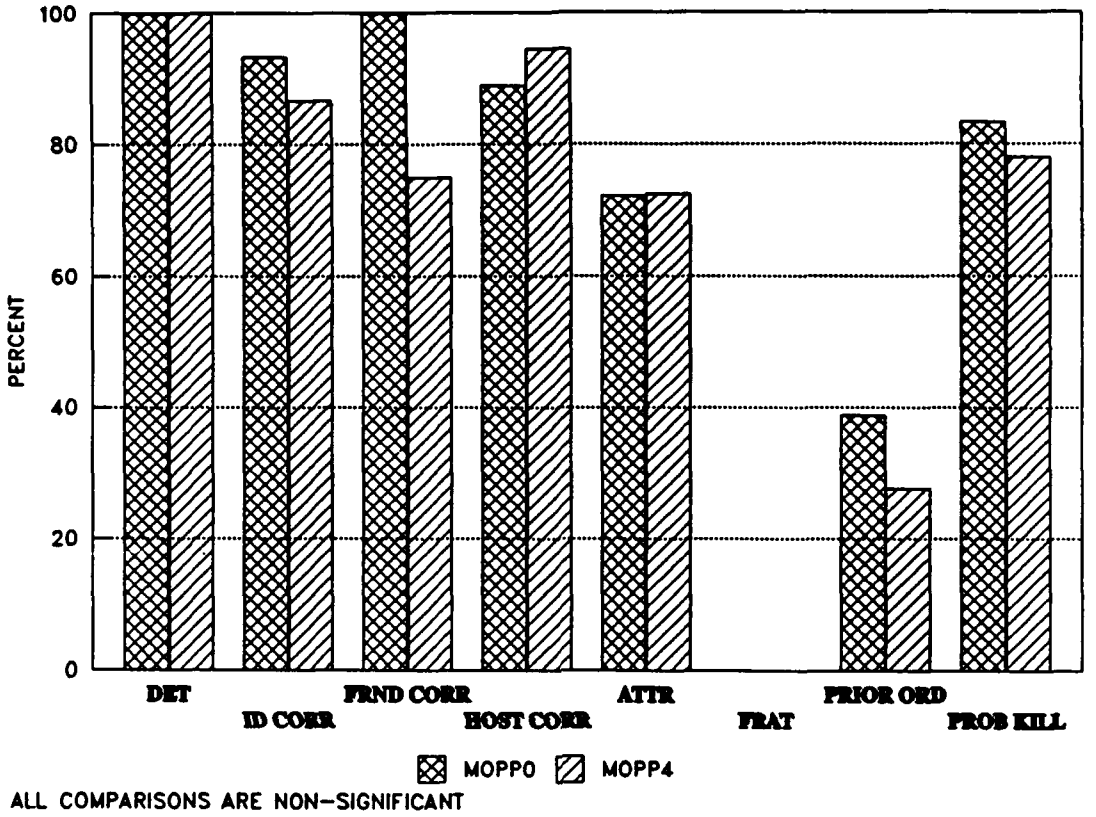

Figure 5. Experiment 1 MOPP0--MOPP4 mean fixed-wing SPM.

Rotary-wing SPM. The rotary-wing SPM means, standard deviations, number of observations, and results of the repeated measures analyses are listed in Table 5. The SPM means are depicted graphically in Figure 6. Like the fixed-wing measures, the MOPP gear had no significant impact on rotary-wing SPM. The CP ensemble apparently does not impair Avenger effectiveness as reflected by SPM.

Table 5

Experiment 1 Mean Rotary-Wing SPM

	MOPP0	MOPP4	RESULTS
Percent Detected (Alerted Trials)			
Mean	100.00	98.00	F(1,5) = 1.00
SD	0	4.90	
N	6	6	
Percent Identified Correctly			
Mean	77.33	72.50	F(1,5) =.25
SD	14.49	14.39	
N	6	6	
Percent Friendly Aircraft Identified Correctly			
Mean	55.33	54.17	F(1,5) = 0
SD	25.15	26.83	
N	6	6	
Percent Hostile Aircraft Identified Correctly			
Mean	92.50	87.50	F(1,5) = .50
SD	11.73	13.69	
N	6	6	
Percent Attrition			
Mean	40.83	39.17	F(1,5) = .01
SD	22.23	20.84	
N	6	6	
Percent Fratricide			
Mean	13.83	8.33	F(1,5) = .42
SD	22.09	12.91	
N	6	6	
Percent Hostile Aircraft "Killed" Prior to Ordnance Release			
Mean	0.0	0.0	
SD	0.0	0.0	
N	6	6	
Probability of Kill			
Mean	100.00	90.33	F(1,5) = 2.43
SD	0.0	15.19	
N	6	6	

All comparisons are non-significant

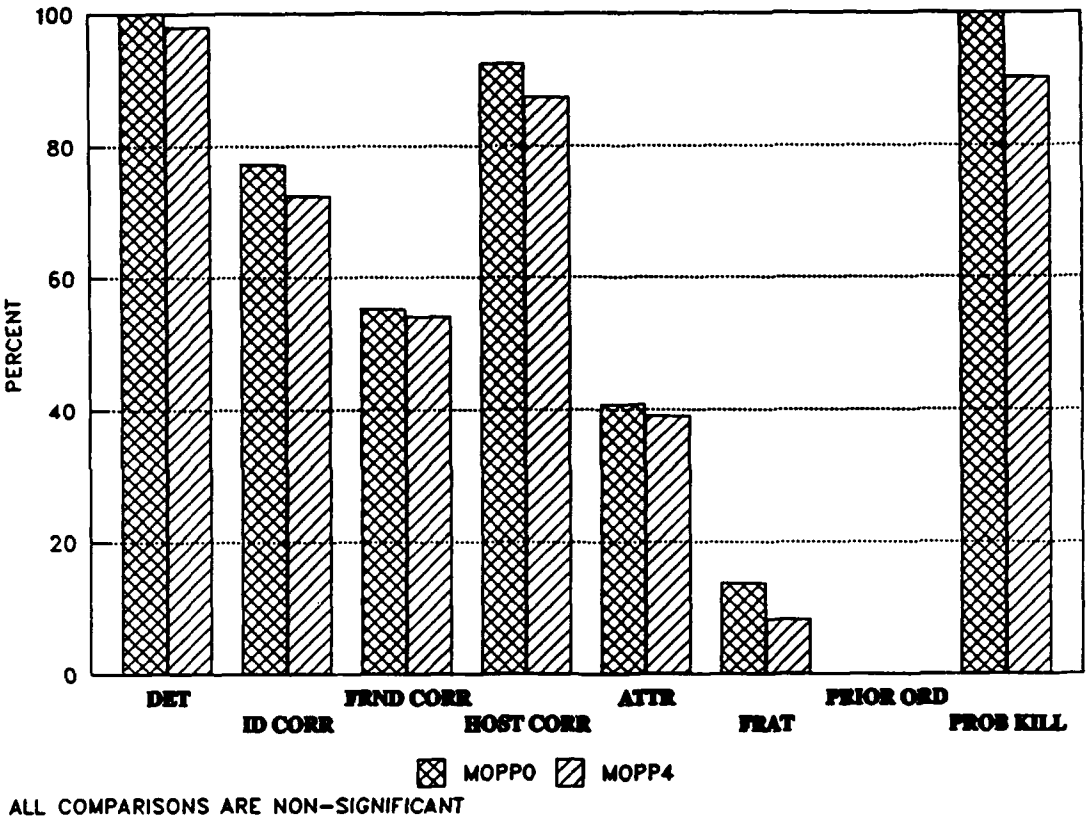

Figure 6. Experiment 1 MOPP0--MOPP4 mean rotary-wing SPM.

Workload Analyses

Participants rated workload on the NASA TLX multidimensional scale after each engagement trial in each clothing condition. A mixed model repeated measures ANOVA was performed on the workload data using the SPSS/PC+ Advanced Statistics software package (Norusis, 1986, pp. B153-B181). Duty position (team chief or gunner) was the between-subjects factor and MOPP level (0 or 4) was the within-subjects factor. The workload means, standard deviations, and number of observations are listed in Table 6. A significance level of .05 has been set for the workload analyses. The means are displayed in graphic form in Figure 7.

There were no significant differences between the ratings given by the team chief and the gunner ($F[1,10] = 2.16$, $p>.05$), no significant effect of the MOPP gear on workload ratings ($F[1,10] = 1.35$, $p>.05$), and no interaction between duty position and MOPP gear ($F[1,10] = 1.11$, $p>.05$). Therefore, it can be concluded that the CP protective ensemble does not increase subjective perception of workload for Avenger teams.

Table 6

Experiment 1 Mean Workload Ratings

	MOPP0	MOPP4
	Team Chief	
Mean	30.27	43.04
SD	13.68	14.31
N	6	6
	Gunner	
Mean	26.73	27.34
SD	14.7	17.46
N	6	6
	Team Chief and Gunner Combined	
Mean	28.50	35.19
SD	12.89	17.29
N	12	12

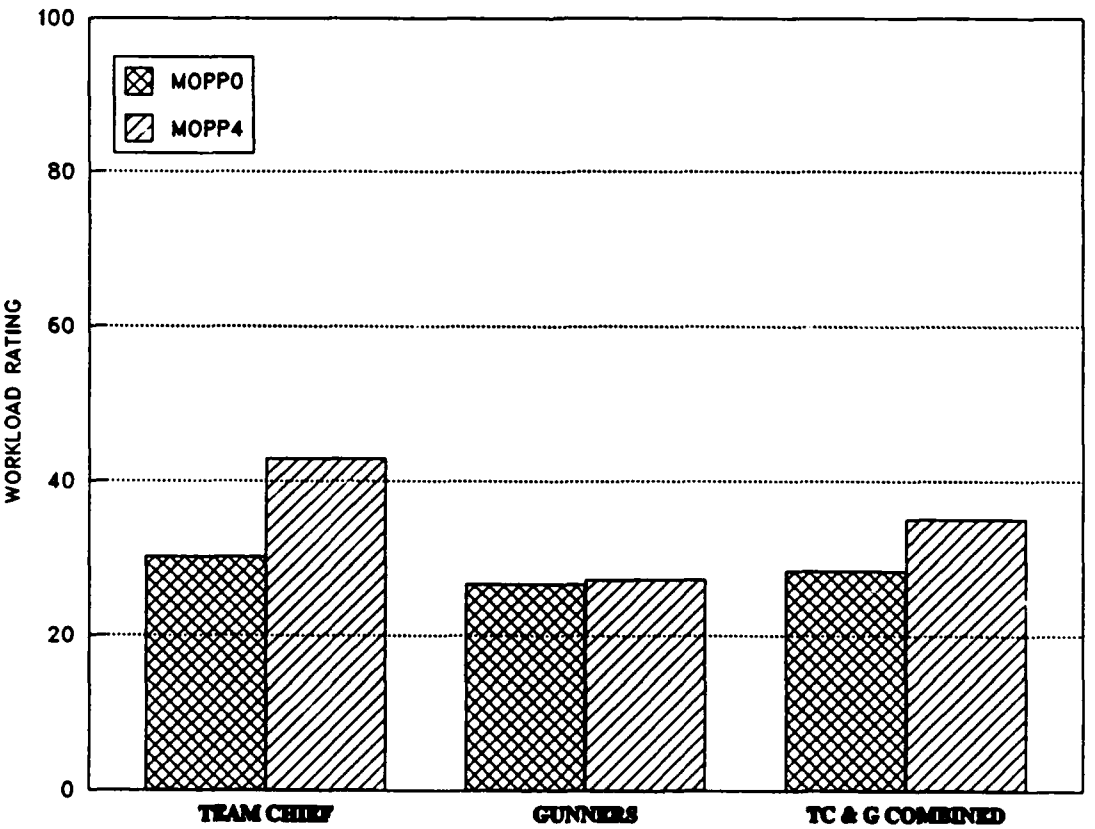

Figure 7. Experiment 1 mean workload ratings.

Although not statistically significant, it is interesting to note at the descriptive level that the team chiefs reported substantially more workload in MOPP4 than in MOPP0. The gunners, on the other hand, reported equivalent workload in each clothing condition. These data contain the suggestion that the reduced FOV which makes the team chief's job more difficult in MOPP4 also increases his perception of workload. The gunner, however, given the technological advantage provided by the easily seen displays and aids, does not experience increased workload in MOPP gear.

Stress Analyses

Participants used the SEQ to rate stress levels (Spielberger, 1983) before and after MOPP0 and MOPP4 engagement trials. The data were analyzed using the Wilcoxon test for within-group comparisons (Bruning & Kintz, 1977). The means, standard deviations, number of observations, and results of the analyses are listed in Table 7. A significance level of .05 has been set for the stress analyses. The means are displayed graphically in Figure 8, along with those for the team chiefs and gunners.

Although the combined team chief and gunner MOPP4 means were elevated relative to the MOPP0 means, both pretest and posttest, these differences were not statistically significant indicating that the CP clothing did not increase subjective perception of stress for the Avenger teams.

Table 7

Experiment 1 Mean Stress Ratings

	MOPP0	MOPP4	RESULTS
	Pretest		
Mean	32.83	38.92	$z = -1.57$
SD	11.29	7.10	
N	12	12	
	Posttest		
Mean	32.83	38.50	$z = -.89$
SD	8.83	10.34	
N	12	12	

All comparisons are non-significant

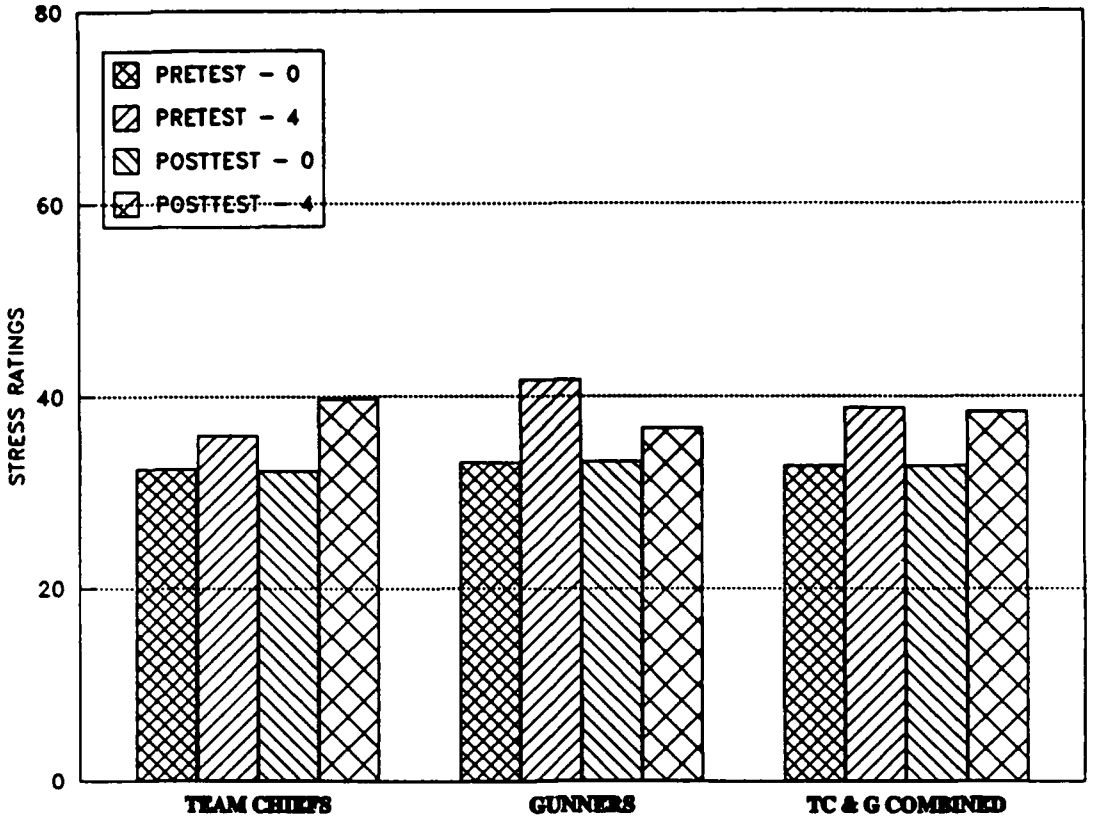

Figure 8. Experiment 1 MOPP0--MOPP4 mean stress ratings.

Experiment 2

Method

The purpose of this experiment was to test the effects of the CP ensemble on Avenger system performance when operated in the static remote emplacement mode. The basic difference between the static stationary deliberate emplacement mode (Experiment 1) and the static remote emplacement mode is that in the remote mode of weapon system operation both team members co-locate within 50 meters of the vehicle and perform their functions from the remote control unit (RCU). Target engagement using the RCU follows a procedure similar to that used inside the turret except that a pointer assembly affixed to the RCU is now used to automatically slew the turret to a visually acquired target. The gunner will also operate the handheld control display terminal (CDT) which has been removed from the turret. This device ensures that the weapon system is ready to fire and is functioning correctly.

Participants

Five of the six Avenger teams from Experiment 1 participated in Experiment 2. A sixth team was unable to participate because of an Avenger weapon system malfunction. Ages of the

participants ranged from 20 to 29 years ($\underline{M}$ = 23.8 years). The sample was comprised of 4 privates first class, 3 specialists, and 3 sergeants.

Apparatus

Range Target System. The Avenger teams were tested at the Range Target System (RTS) engagement simulation facility located at White Sands Missile Range, New Mexico. The RTS facility is described in Experiment 1.

Avenger weapon system. The Avenger weapon system is described in Experiment 1.

Procedure

Avenger team members changed duty positions for Experiment 2; i.e., the team chief now acted as gunner and the gunner acted as the team chief. The switch in duty positions is in keeping with the expectation that each squad member will be required to perform all tasks associated with both positions (FM 44-31, 1989). A total of five Avenger teams were tested.

Experiment 2 followed the same procedure as Experiment 1 with the exception of weapon system mode of operation and change of duty position.

Mean ambient temperatures in the morning were 57.2°F and 45.2°F for day 1 and day 2, respectively, and 68.6°F and 50°F in the afternoon.

Results and Discussion

Like Experiment 1, two general classes of performance measures were collected--Task Performance Measures (TPM) and Summary Performance Measures (SPM). Recall that TPM are expressed as ranges for the fixed-wing aircraft and as elapsed time for rotary-wing aircraft. TPM are available on a trial-by-trial basis. SPM are collected by summing over scenarios and are expressed as percentages. The TPM are presented first.

Task Performance Measures

Fixed-wing TPM. Table 8 contains the fixed-wing TPM means, standard deviations, number of observations, and results of the single factor repeated measures ANOVAs (Norusis, 1986, pp. B153-B181). The TPM means are represented graphically in Figure 9. Positive ranges are incoming aircraft; negative ranges are outgoing aircraft.

The team chief's ability to detect and identify aircraft was once again significantly impaired by the MOPP gear. This finding was expected because the team chief's job remains unchanged regardless of Avenger mode of operation. The gunner's performance, however, was not significantly degraded by the MOPP

gear, even though he was no longer in the turret. These findings are consistent with those from Experiment 1.

Table 8

Experiment 2 Mean Fixed-Wing TPM

	MOPP0	MOPP4	RESULTS
DETECT (km) Alerted Trials			
Mean	9.83	8.09	F(1,4) = 15.61 *
SD	2.19	1.48	
N	5	5	
IFF (km)			
Mean	6.97	4.16	F(1,4) = 4.15
SD	1.34	4.21	
N	5	5	
ID (km)			
Mean	5.71	3.67	F(1,4) = 103.67 **
SD	2.24	2.24	
N	5	5	
UNCAGE VERIFY (km)			
Mean	2.47	1.25	F(1,4) = .63
SD	1.73	2.95	
N	5	5	
FIRE (km)			
Mean	1.86	-.71	F(1,4) = 3.69
SD	2.03	2.62	
N	5	5	

* $p<.02$
** $p<.001$

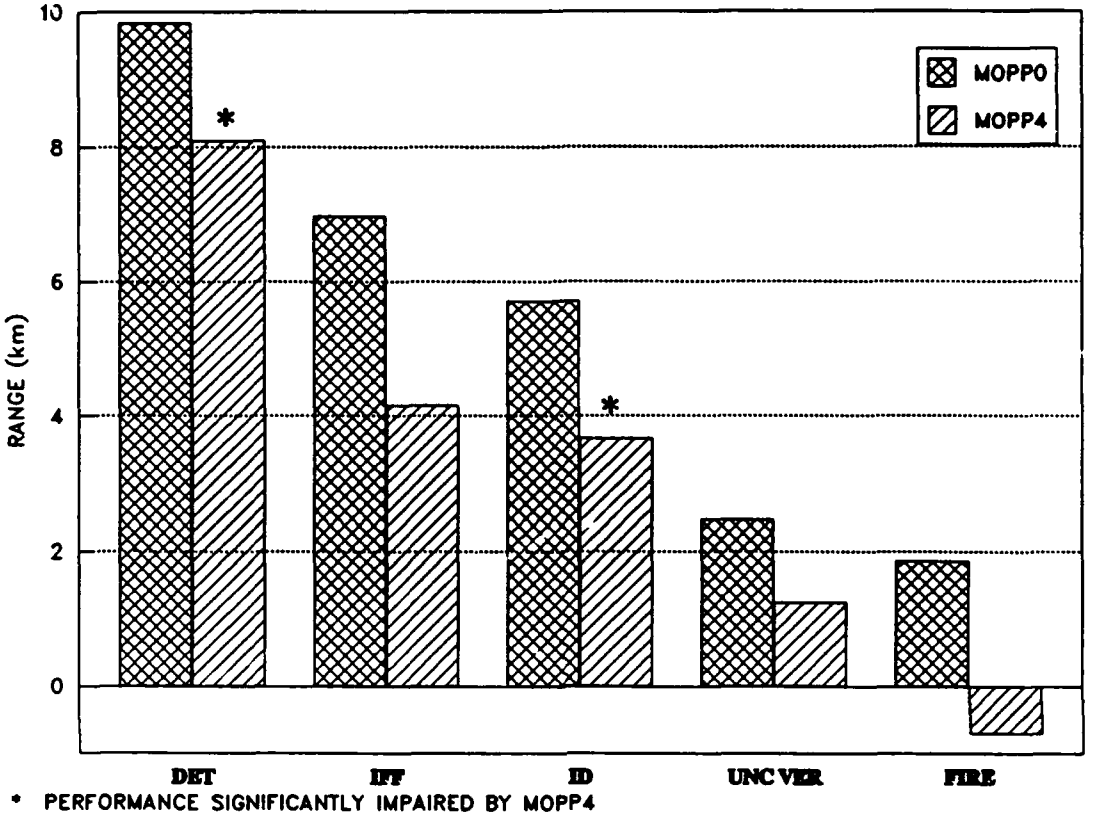

Figure 9. Experiment 2 MOPP0--MOPP4 mean fixed-wing TPM.

Rotary-wing TPM. The rotary-wing TPM means, standard deviations, number of observations, and results of the analyses are listed in Table 9. The means are represented graphically in Figure 10. All times to perform an action were faster in MOPP0. Three TPM, DET-ID, DET-FIRE, and AVL-FIRE were significantly degraded by the CP clothing. Like Experiment 1, the team chief's ability to identify rotary-wing aircraft was impaired by the MOPP gear. Comparable impairments as a function of the MOPP gear were not found for the DET-FIRE and AVL-FIRE TPM in the first experiment, however.

Once again, like Experiment 1, the ID-UNCVER means were greater than the ID-FIRE means, and of course this should not be the case because the "uncage verify" response takes place before the "fire" response. Subsequent analyses disclosed once more that the ID-UNCVER means contain two different subgroups--those for whom "uncage verify" was the last act in the engagement sequence and those for whom "fire" was the last act in the engagement sequence. The means for the subgroups appear in Table 10. The team chiefs apparently exercise caution when assigning a "friendly" designation to an aircraft thereby increasing the time

from detection to identification relative to that for a "hostile" designation.

Table 9

Experiment 2 Mean Rotary-Wing TPM

	MOPP0	MOPP4	RESULTS
AVL-DET			
Mean	8.36	10.18	F(1,4) = 1.19
SD	1.54	3.85	
N	5	5	
DET-IFF			
Mean	10.56	18.66	F(1,4) = 3.85
SD	5.61	10.22	
N	5	5	
DET-ID			
Mean	12.00	16.42	F(1,4) = 9.44 *
SD	3.41	4.67	
N	5	5	
ID-UNCVER			
Mean	13.63	19.40	F(1,4) = .61
SD	10.11	13.48	
N	5	5	
ID-FIRE			
Mean	11.90	14.53	F(1,3) = .31
SD	5.67	9.33	
N	5	5	
DET-FIRE			
Mean	22.65	32.28	F(1,3) = 17.93 *
SD	7.32	11.07	
N	5	5	
AVL-FIRE			
Mean	30.03	39.88	F(1,3) = 17.0 *
SD	7.82	11.03	
N	5	5	

* $p<.05$

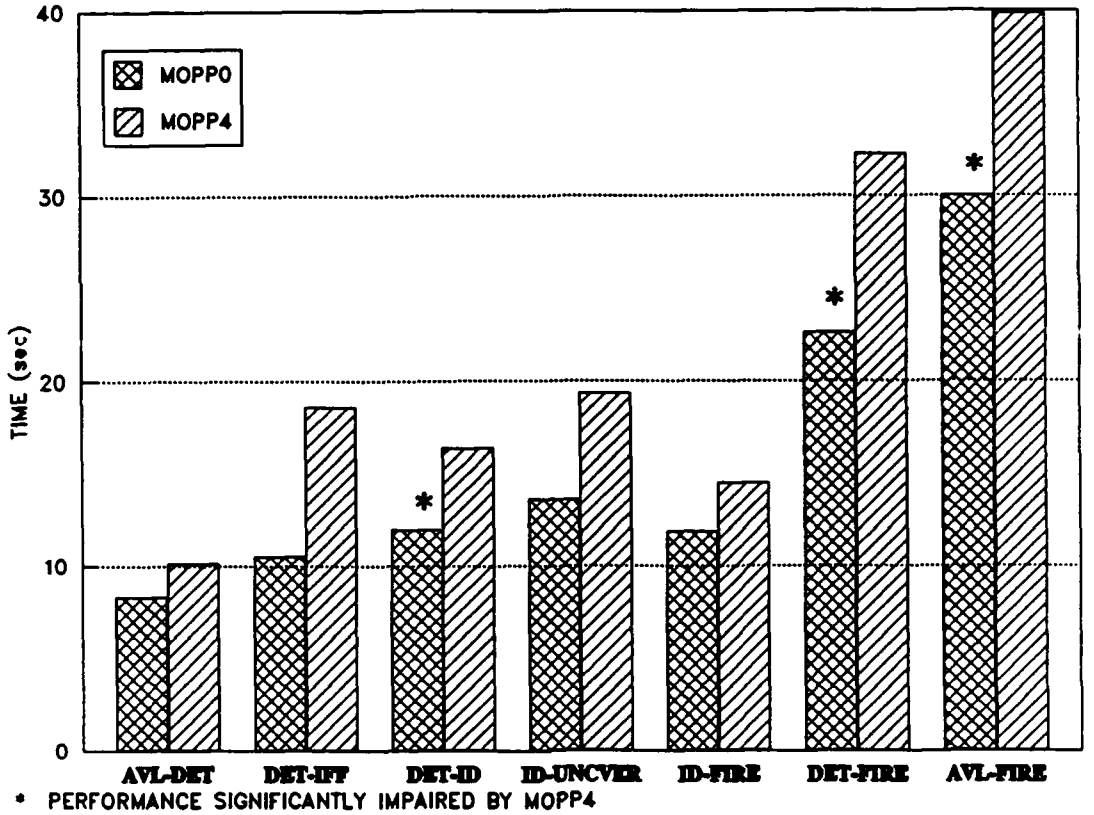

Figure 10. Experiment 2 MOPP0--MOPP4 mean rotary-wing TPM.

Table 10

Experiment 2 "Last Act" Means

	Last Act	
	Uncage Verify	Fire
	MOPP0	
Mean	26.33	9.98
SD	6.60	5.87
N	2	4
	MOPP4	
Mean	26.44	13.55
SD	19.53	9.23
N	3	5

Summary Performance Measures

Fixed-wing SPM. Table 11 contains the means, standard deviations, number of observations, and results of the analyses performed on the fixed-wing SPM means. The SPM means appear in graphic form in Figure 11.

Table 11

Experiment 2 Mean Fixed-Wing SPM

	MOPP0	MOPP4	RESULTS
Percent Detected (Alerted Trials)			
Mean	100.00	100.00	
SD	0	0	
N	5	5	
Percent Identified Correctly			
Mean	88.00	96.00	F(1,4) =2.67
SD	10.95	8.94	
N	5	5	
Percent Friendly Aircraft Identified Correctly			
Mean	90.00	100.00	F(1,4) = 1.00
SD	22.36	0	
N	5	5	
Percent Hostile Aircraft Identified Correctly			
Mean	86.80	93.40	F(1,4) = 1.00
SD	18.08	14.76	
N	5	5	
Percent Attrition			
Mean	66.60	13.20	F(1,4) = 7.14 *
SD	33.50	18.08	
N	5	5	
Percent Fratricide			
Mean	10.00	0.0	F(1,4) = 1.00
SD	22.36	0	
N	5	5	
Percent Hostile Aircraft "Killed" Prior to Ordnance Release			
Mean	26.60	6.60	F(1,4) = 2.24
SD	27.97	14.76	
N	5	5	
Probability of Kill			
Mean	80.00	30.00	F(1,4) = 5.00 *
SD	27.39	44.72	
N	5	5	

* $p<.10$

Only two TPM, Percent Attrition and Probability of Kill, were significantly impaired by the MOPP gear when the Avenger weapon system was operated in the static remote mode. Comparable results were not found in Experiment 1.

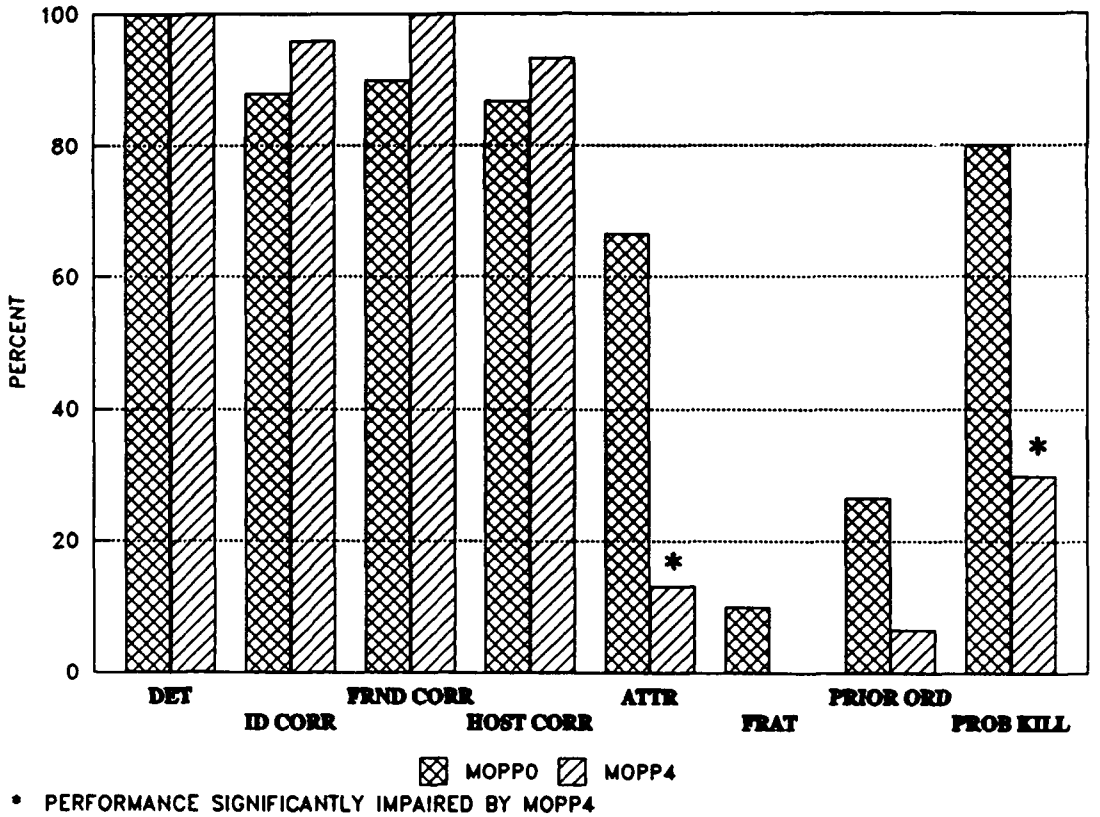

Figure 11. Experiment 2 MOPP0--MOPP4 mean fixed-wing SPM.

Rotary-wing SPM. The rotary-wing SPM means, standard deviations, number of observations and results of the analyses performed on the means appear in Table 12. The means are represented graphically in Figure 13. Although five of eight pairs of means were ordered as predicted, only the percentage of aircraft identified correctly was significantly impacted by the MOPP gear.

Table 12

Experiment 2 Mean Rotary-Wing SPM

	MOPP0	MOPP4	RESULTS
Percent Detected (Alerted Trials)			
Mean	100.00	100.0	
SD	0	0	
N	5	5	
Percent Identified Correctly			
Mean	80.20	67.80	F(1,4) = 2.03
SD	18.73	18.86	
N	5	5	
Percent Friendly Aircraft Identified Correctly			
Mean	75.00	53.40	F(1,4) = 7.72 *
SD	30.62	22.69	
N	5	5	
Percent Hostile Aircraft Identified Correctly			
Mean	85.00	78.00	F(1,4) = .15
SD	22.36	22.80	
N	5	5	
Percent Attrition			
Mean	45.00	28.00	F(1,4) = .92
SD	34.64	30.33	
N	5	5	
Percent Fratricide			
Mean	15.00	29.80	F(1,4) = 1.83
SD	22.36	4.38	
N	6	6	
Percent Hostile Aircraft "Killed" Prior to Ordnance Release			
Mean	5.00	0.0	F(1,4) = 1.00
SD	11.18	0.0	
N	5	5	
Probability of Kill			
Mean	80.00	100.00	F(1,4) = 1.00
SD	44.72	0.0	
N	5	5	

* $p<.05$

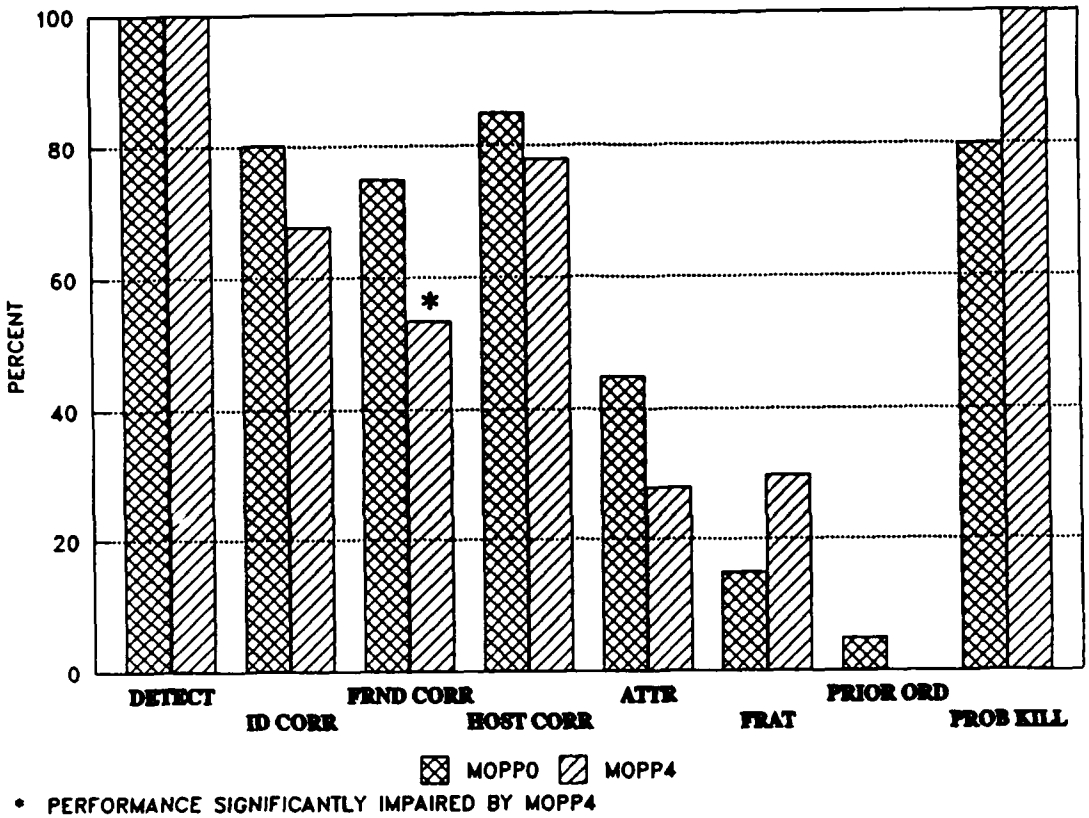

Figure 12. Experiment 2 MOPP0--MOPP4 mean rotary-wing SPM.

Workload Analyses

Workload ratings were given after each engagement trial using the NASA TLX. Ratings were analyzed using a mixed-model repeated measures ANOVA (Norusis, 1986, pp. B153-B181). Duty position (team chief or gunner) was the between-subjects factor and MOPP level (0 or 4) was the within-subjects factor. Table 13 contains the means, standard deviations, and number of observations for both clothing conditions. The workload means are displayed graphically in Figure 13.

There were no significant differences between the responses given by the team chief and the gunner ($F[1,8] = 1.13$, $p>.05$), no significant effects of the MOPP gear ($F[1,8] = .74$, $p>.05$), and no interaction of duty position and MOPP gear ($F[1,8] = 1.58$, $p>.05$).

Like Experiment 1, the team chief reports greater workload in MOPP4 and the gunner reports equivalent workload in both clothing conditions. These findings generate confidence that the ratings are definitely a function of the duty position because (1) they reflect the technology available to the gunner, and (2) the relation of the ratings remained the same even though the team members had switched duty positions for this experiment.

The workload and performance data considered together support both the contention that the team chief's job is seriously affected by the protective mask and the notion that the advanced technology available to the gunner mitigates the negative effects of the mask.

Table 13

Experiment 2 Mean Workload Ratings

	MOPP0	MOPP4
	Team Chief	
Mean	26.90	34.83
SD	23.72	14.30
N	5	5
	Gunner	
Mean	42.54	41.05
SD	13.66	15.48
N	5	5
	Team Chief and Gunner Combined	
Mean	34.72	37.94
SD	20.02	14.43
N	10	10

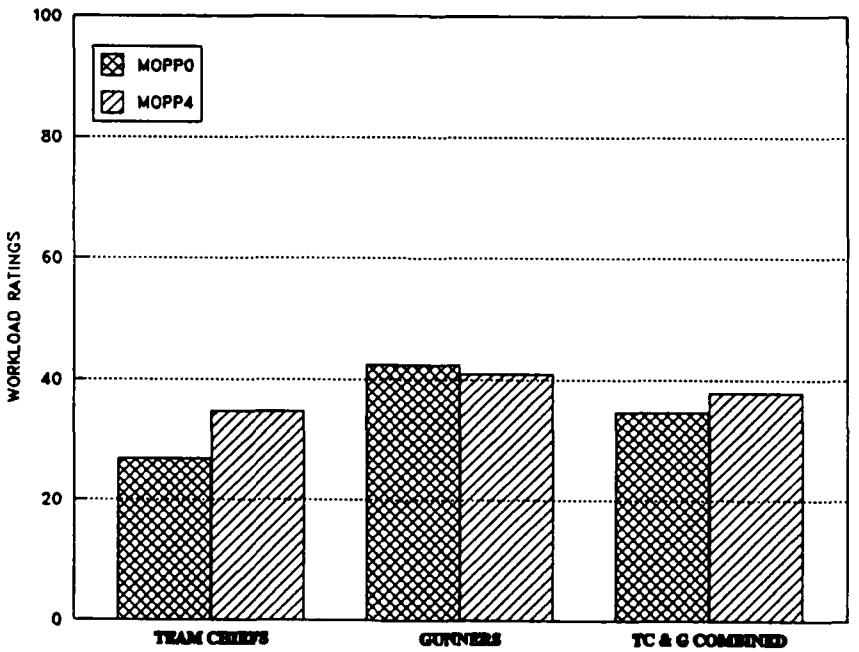

Figure 13. Experiment 2 MOPP0--MOPP4 mean workload ratings.

Stress Analyses

Participants used the SEQ to rate stress levels at the beginning and end of engagement trials in each clothing condition. The Wilcoxon test for within-group comparisons was used to analyze the ratings (Bruning & Kintz, 1977). Table 14 contains the means, standard deviations, number of observations, and results of the analyses. The means are graphically displayed in Figure 14, along with those for the team chiefs and gunners.

Table 14

Experiment 2 Mean Stress Ratings

	MOPP0	MOPP4	RESULTS
	Pretest		
Mean	32.40	36.40	$z = -1.78$, $p<.07$
SD	11.08	9.08	
N	10	10	
	Posttest		
Mean	30.70	36.30	$z = -1.68$, $p<.09$
SD	8.15	8.84	
N	10	10	

Comparisons are non-significant

Like Experiment 1, the MOPP4 means were elevated with respect to the MOPP0 means, but the differences were not significant, pretest or posttest. Unlike the performance and workload data, the stress ratings do not reflect either the impact of the MOPP gear on the team chief's performance or the technology available to the gunner.

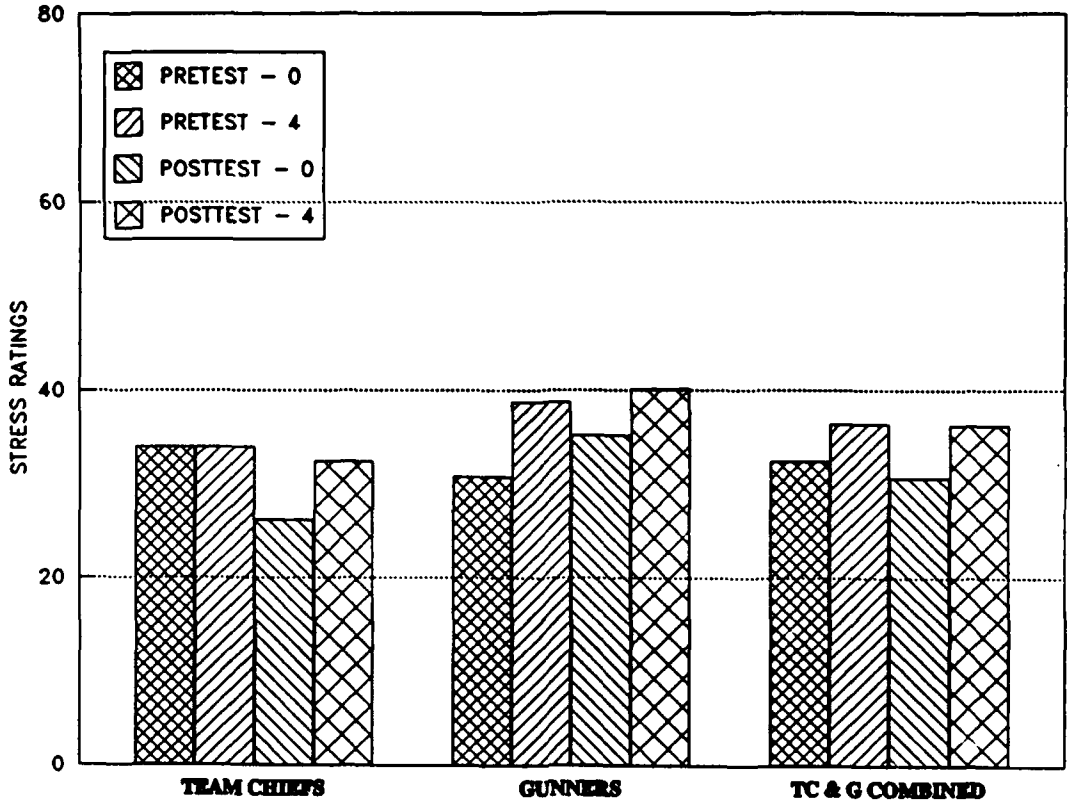

Figure 14. Experiment 2 MOPP0--MOPP4 mean stress ratings.

General Discussion

Regardless of mode of operation of the Avenger weapon system, the team chief's engagement performance was consistently impaired by the CP clothing. These results are consistent with those from research employing Stinger team chiefs (Johnson & Silver, 1992; in preparation). Those Air Defenders also suffered a significant performance decrement when wearing the CP clothing. The reduced FOV caused by the CP mask is believed to be the primary source of the performance decrement for both Avenger and Stinger team chiefs.

Johnson and Silver (1992) and Silver and Lockhart (in preparation) have demonstrated that it is possible to circumvent the problems created by the reduced FOV. Johnson and Silver simulated a cuing device which provides soldiers with precise information regarding the range, azimuth, number, and type of approaching aircraft. Engagement performance was significantly better for the cued teams than for teams who were not cued. Using another approach, Silver and Lockhart mechanically restored the FOV reduced by the CP mask by modifying the team chief's binoculars. Although their results cannot be construed as conclusive, they provide support for the notion that restoring the FOV improves performance.

Unlike their Stinger counterparts, Avenger gunners show no ill effects of the MOPP gear. Regardless of mode of weapon system operation, the CP clothing did not impair engagement performance. It is believed that the technological advantages provided by the Avenger weapon system overcome the disadvantages associated with the MOPP gear.

Regardless of mode of Avenger weapon system operation, fixed-wing and rotary-wing SPM were essentially unaffected by the CP clothing. These results are consistent with those from Stinger research (Johnson & Silver, 1992; in preparation). It seems that for Avenger and Stinger teams, the MOPP gear does not impact these measures of overall mission success.

The results of the present study and of prior research document the negative effects of the CP mask on team chief performance. It is possible that the detrimental effects of the mask might be overcome by equipping the team chief with a cuing device that provides precise information and/or by equipping him with binoculars modified to restore his FOV. These remedies may significantly increase his effectiveness in a chemical environment and significantly contribute to his ability to survive on the battlefield. The use of these aids for circumventing the problems associated with a reduced FOV should not be limited to Avenger and Stinger team chiefs only. The problem of reduced FOV caused by the CP mask goes beyond the Air Defense Community and beyond the Army. It is a problem with military-wide ramifications and the suggestions offered above pertain in any circumstance in which the CP mask effectively reduces FOV.

Although it has been shown that the problems created by a reduced FOV can be obviated for Stinger gunners as well as team chiefs (Silver & Lockhart, in preparation), it may be that the Avenger weapon system is the better choice on a battlefield that is subject to chemical attack because the superior technology available to the Avenger gunner in the form of easily seen displays and aids increases his immunity to the negative effects of the CP mask.

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